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WILDLIFE RISKS ASSOCIATED WITH PASSAGE OF CONTAMINATED, ANADROMOUS FISH AT FEDERAL ENERGY REGULATORY COMMISSION LICENSED DAMS IN MICHIGAN

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EXECUTIVE SUMMARY

The purpose of this paper is to assess the issue of anadromous fish passage at Federal Energy Regulatory Commission (FERC) licensed hydropower dams in Michigan and whether contaminants in these anadromous fish pose a significant hazard to wildlife, especially the bald eagle. Existing information developed by the Service, including Great Lakes specific regression analysis of addled egg concentrations and measures of reproductive productivity by us, strongly suggests that eagle reproductive outcomes on the Great Lakes and anadromous fish influenced stream reaches continue to be significantly impaired by at least three organochlorine contaminants; PCBs, DDE and dieldrin. Bald eagle eggs analyzed for contaminant residues exceed concentrations necessary for healthy populations by a few fold to almost three orders of magnitude. Such contamination is consistent with eagles obtaining the majority of egg burdens from Great Lakes fish, according to published data on biomagnification factors from Great Lakes forage fish to colonial waterbird eggs. Certain wildlife species, especially colonial waterbirds and fish-eating or diving ducks, can increase the eagle's contaminant exposure beyond that obtained by preying exclusively on fish. Other species, such as the mink would likely suffer further population declines from fish passage into currently protected upstream reaches. This species is a sensitive ecosystem health indicator for PCBs.

Based on the data analysis contained in this white paper, we recommend that the Service seek a position on the FERC licenses which reserves our right to prescribe fish passage until after the following are achieved: (1) contaminants of concern are lowered to acceptable concentrations (No Observable Adverse Effect Concentration in the most sensitive species) in eagle eggs and fish (based on biomagnification factors from fish to eagle egg) used as food for eagles and (2) that measures of bald eagle reproductive success indicating a healthy population be achieved on respective Great Lakes shorelines/existing Great Lakes tributaries influenced by presently contaminated anadromous fish runs.

Because the issue affects several Service program responsibilities, significant coordination between our Federal Aid, Fisheries, Endangered Species, Contaminants, and the Enhancement programs is necessary to assure a uniform position and assignment of appropriate responsibilities relative to anadromous fish assessments and operational initiatives.

INTRODUCTION

The progress toward recovery of the bald eagle population within the Great Lakes basin has paralleled the improved status of the species across North America. Primary credit has been attributed to the decline of contaminants in eagles and their prey base, particularly DDT and metabolites. Contributing to the improving status has been an aggressive program by natural resource agencies in the management/protection/enhancement of eagles and their habitat, and through programs for public awareness and education. These efforts have resulted in a documented improvement in adult survival, productivity and numbers of breeding areas on a jurisdictional and regional basis.

Mortality and injury to non-nestling eagles continues to be dominated by trauma (impacts with vehicles, structures, etc.), (Franson 1990, Martell 1990). Necropsy results show that lead and dieldrin poisoning are secondary to trauma as causes of death to Great Lakes eagles. Trapping and shooting are secondary causes of injury to eagles. Shooting injuries are closely associated with the opening of waterfowl seasons. Successfully rehabilitated eagles are released back into the wild when possible, and are being monitored for subsequent survival and reproductive efforts. Hacking of eaglets in Ontario (Robinson 1990) and fostering of eaglets in Ohio (Shieldcastle 1990) have been highly successful in fledging eaglets along the shorelines of Lake Erie. However, it is too early to determine whether these efforts will result in the return of these birds to Lake Erie as breeding adults.

Despite this improvement, the bald eagle subpopulation located along the Great Lakes shorelines, connecting channels and embayments is lagging behind the recovery of inland eagles. No bald eagle breeding areas are known to exist along the Lake Superior shoreline of Minnesota (Mooty 1990), the Lake Huron shoreline of Ontario, and the entire shoreline of Lake Ontario (Government of Canada 1991). Furthermore, shoreline eagles in Wisconsin, Ohio and Michigan produce less young per occupied nest and have lower success rates than eagles in adjacent inland areas (Kozie and Anderson 1991, Appendix 1). According to our data on Michigan and Ohio, the coastal subpopulation is composed of a higher percentage of young adult pairs than in inland populations (Appendix 2). We have determined that these young, inexperienced pairs exhibit lower rates of productivity for the first 2 years than older, more experienced pairs. However, our data indicate that experienced Great Lakes pairs (3+ years) in Michigan and Ohio have similar reproductive outcomes to inexperienced pairs (1-2 years), and are significantly less productive than inland experienced pairs (Appendix 3). Furthermore, Great Lakes breeding pairs in the state of Michigan along Lakes Michigan and Huron shorelines of Michigan exhibit a gradual decline in reproductive success over the period of breeding area occupation (Appendix 4). In shoreline nesting territories, field observations among eagle biologists have noted replacement of individuals within breeding pairs and is suggestive of higher turnover rates among adults along the Wisconsin and Michigan shorelines (Kozie and Anderson 1991, Bowerman 1991).

In Wisconsin, the lower reproductive rates of coastal eagles may in part be an outcome of higher rates of nestling mortality than in inland areas (Kozie and Anderson 1991). As a result of these reproductive differences between inland and coastal subpopulations, we suspect that the shoreline subpopulation is unable to sustain itself and is being maintained by surplus immigrants from inland areas.

MAJOR ISSUES

The U.S. Fish and Wildlife Service, through the East Lansing Field Office (ELFO), has the legal mandate to make recommendations to the Federal Energy Regulatory Commission regarding terms and conditions protecting trustee resources during the licensing and relicensing of hydroelectric facilities. The ELFO Environmental Contaminants program raised the concern over possible contaminant impacts to inland fish and wildlife resulting from anticipated proposals for upstream passage of Great Lakes anadromous fish on four major river systems in the lower peninsula of Michigan. Recently, the Michigan Department of Natural Resources has indicated that fish passage would be required but that specific details were not known (Consumers Power Co. 1991a).

The primary issue facing the Service is to determine whether inland extension of anadromous fish upstream of existing hydroelectric dams will pose an unacceptable risk to the health of fish and wildlife inhabiting these inland areas which are presently considered relatively free of contamination. One of the issues to resolve is to determine what contaminant concentration(s) will be necessary in anadromous fish to not have a detrimental impact on specific species and thus allow the Service to support fish passage either by the installation of fish passage facilities or dam removals.

The issue of anadromous fish passage relative to contaminants has implications regarding other programs of the Service and Great Lakes community. Specifically, the Service is in the process of initiating Natural Resource Damage Assessments, under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), also known as "Superfund" and the Superfund Amendments and Reauthorization Act of 1986 (SARA). We also are involved with the multifaceted programs of the International Joint Commission and the EPA under the Great Lakes Water Quality Agreement, such as the Remedial Action Plan process for "Areas of Concern", the development of Lakewide Management Plans for Critical Pollutants, the development of Ecosystem Objectives and Ecosystem Indicators and the Assessment and Remediation of Contaminated Sediments Program under Section 318 of the Clean Water Act. Additionally, the cross-program interests of the Service, specifically the Federal Aid and the Endangered Species Programs both have ties to the issue of anadromous fish passage. All of the programs external to the Service have increasingly been dependant on the use of bioeffects on wildlife to "make the case" for cleanup actions on the Great Lakes that will result in long-term, enhanced populations of colonial waterbirds, the bald eagle, and the mink and river otter.

The Service, through the Endangered Species Program, has the responsibility to assure that the recovery of the bald eagle proceeds according to the Northern States Bald Eagle Recovery Plan (U.S. Fish and Wildlife Service 1983). The plan specifies Michigan to have 140 nesting pairs (currently met) and with average annual productivity of at least 1.0 young per occupied nest (currently almost met, 1981-1990 statewide mean = 0.95). The conservation of the species is considered in all major Federal actions pursuant to Section 7 consultations. Recovery 2000, for example, addresses limiting factors for the eagle and states that "The species needs a contaminant-free prey base (fish and waterfowl)..." and "Recovery seems assured if current levels of protection and monitoring are continued...". The FERC needs to consult with the Service because of the presence of the bald eagle in the license area streams and Lake shorelines. Lastly, Federal aid from the Service cooperatively funds many of Michigan's fishery programs. The potential exists for an internal Service conflict to develop where Federal aid supports state proposals for anadromous fish passage in areas that have contaminants implications to threatened and endangered species.

USE OF ENVIRONMENTAL INDICATORS

The complexity of the food web within the Great Lakes basin, as illustrated in Appendix 5, precludes the consideration and evaluation of all trophic levels and compartments. As a result, a select few species or species groups need to be chosen as ecosystem indicators of environmental conditions. The International Joint Commission (IJC) has adopted this approach for monitoring Great Lakes water quality in the future. Within the IJC, the Ecosystem Objectives Committee has developed 12 criteria for the selection of Great Lakes ecosystem indicators. Not all criteria must be met by a species or species group to be considered for nomination. Criteria of interest to the issue at hand include the following:

* has a broad distribution in the system,
* is indigenous and maintains itself through natural reproduction,
* interacts directly with many components of its ecosystem,
* has well documented and quantifiable niche dimensions,
* exhibits a gradual response to a variety of human induced stresses,
* responds to stresses in a manner that is both identifiable and quantifiable, and
* is recognized as important to humans.

The Biological Effects Subcommittee to the IJC's Science Advisory Board is currently evaluating species/species groups for nomination as indicator species for Great Lakes water quality. To date, the bald eagle, mink/otter, colonial waterbird group, and lake trout (salmonids) are being evaluated.

The ELFO has benefitted from this effort by providing a focus on individual species; by elucidating broad criteria for species selection; by facilitating monitoring and effects studies among agencies and by sanctioning the use of indicators of ecosystem health. We have chosen the bald eagle, mink, and colonial waterbird group as ecosystem indicators for fish passage/risk assessment issue in Michigan. These species satisfy many of the above criteria, and in aggregate involve most possible contaminant pathways through the food web to terminal predators.

The bald eagle is a top trophic level predator subsisting on a diverse, mobile and largely aquatic prey base. Reproduction is known to be most affected by DDE, although the effects are highly correlated with PCBs (Wiemeyer et al. 1984). The species has a wide distribution throughout most of the state, and has made major improvements in the numbers of breeding pairs and productivity in the inland areas under consideration for fish passage. The Federally threatened status of the species in Michigan, its designation as the national symbol, and its easily recognizable form give the species high public profile and importance.

The mink is another species which depends on a largely aquatic prey base (Baker 1983). The species is known to be highly sensitive to PCBs resulting in adverse impacts to reproduction from poor kit survival (see review in IJC 1989). Deformities in new born kits are now well documented to PCB exposure through placental transfer (Michigan State University and U.S. Fish and Wildlife Service unpublished data). In comparison, bioeffects on the mink from DDE and dieldrin are believed to be slight. Mink have a state-wide distribution and are important to rural economies via trapping as well as general aesthetics (Baker 1983).

The colonial waterbird group has been well studied within the Great Lakes basin. Most species have made major improvements in numbers of breeding pairs and distribution of colonies in coastal and inland areas. Several species within the group, (Forster's, common and caspian terns and double-crested cormorants) are known to be sensitive to PCB exposure and exhibit poor reproductive efforts in coastal areas (Gilman et al 1991, Government of Canada 1991, Gilbertson et al 1991). Known bioeffects include hard tissue deformities, edema and gastroschisis in embryos, and wasting syndrome in hatchlings. These species distinguish themselves from the mink and bald eagle by subsisting exclusively on an aquatic prey base of small fish and macroinvertebrates.

BACKGROUND INFORMATION

Presently, there is a strong link emerging between the poor reproductive success of shoreline bald eagles and persistent toxic chemicals. In Wisconsin, a correlation is present between contaminated addled eggs and areas with fish and waterfowl consumption advisories (Shapiro-Hurley 1990). In Michigan and Ohio, concentrations of total PCBs, p,p'-DDE and dieldrin are significantly higher in addled eggs recovered from shoreline nests than those from inland nests (Best et al. 1990). Additionally, concentrations of these contaminants are inversely correlated to two measures of productivity for four shoreline reaches and four inland realms (Appendix 6).

For example, the relationships between the number of eaglets fledged per occupied breeding area (y) and the contaminant residues in addled eggs (x_1 - total PCBs, x_2 - p,p'-DDE, x_3 - dieldrin), is described by the natural logarithmic decay curves:

$$y = -0.177 \ln x_1 + 1.317 \qquad r^2 = 0.802 \text{ , total PCBs;}$$

$$y = -0.157 \ln x_2 + 1.082 \qquad r^2 = 0.626 \text{ , p,p'-DDE;}$$

$$y = -0.156 \ln x_3 + 0.649 \qquad r^2 = 0.821 \text{ , dieldrin.}$$

The shapes of the curves described by these equations suggest the existence of a threshold contaminant concentration where changes in productivity are most pronounced. As a predictive tool, the equations suggest that reproduction along a shoreline reach or in an inland realm which is indicative of a healthy subpopulation ($\geq$ 1.0 young/occupied breeding area), should be associated with addled egg residues of <6.0 ug/g (parts per million) total PCBs, <1.7 ug/g p,p'-DDE, and <0.11 ug/g dieldrin, fresh wet weight.

Nests along the Lake Michigan and Huron shorelines exhibited the lowest reproductive rates and the highest contaminant residues in addled eggs (Table 1). This association between poor productivity and elevated egg residues, is consistent with the Service's nationwide study in the U.S. which correlated egg residues of < 4.0 ug/g total PCBs, < 1.0 ug/g p,p'-DDE and < 0.1 ug/g dieldrin (fresh wet weight) with normal reproduction (Wiemeyer et al. 1984, Wiemeyer 1990). It should be noted that these cited values are in close agreement with the values similarly derived above, but specific to the Great Lakes basin and an Alaskan control site (Appendix 7). To the non-technical reader, these derived values are based on observed measures of productivity and egg concentrations. The egg contaminant concentrations are predicted by solving the regression equation for a specified level of reproductive success (a healthy subpopulation). In Wisconsin, contaminants were detected in higher concentrations in eaglet carcasses recovered from Lake Superior shoreline nests than from inland nests (Kozie and Anderson 1991). For eaglets surviving to the near-fledgling stage in Michigan, blood sera concentrations of PCBs and p,p'-DDE were six times higher in Great Lakes eaglets than in inland eaglets (Best et al. 1990, Bowerman and Giesy 1991).

Table 1. Measures of Productivity and Addled Egg Residues, Michigan, Ohio and Alaska, 1986-1990.

Lake Basin/Region	Addled Egg Residues[1] (ug/g Fresh Wet Weight)			Productivity[2]	
	PCBs	p,p'-DDE	Dieldrin	Prod.1[3]	Prod.2[4]
L. Huron	76.7	20.5	1.16	0.59	41.2
L. Michigan	41.0	20.1	1.32	0.68	48.0
L. Erie	22.1	3.4	0.43	0.75	52.6
L. Superior	10.1	4.5	0.25	0.84	55.4
Inland Ohio	10.7	1.9	0.19	0.71	57.1
Inland Mich.-U.P.	7.5	3.2	0.24	0.93	59.7
Inland Mich.-L.P.	8.2	2.7	0.11	1.14	71.8
Interior Alaska	1.4	0.5	0.02	1.29	76.8

[1] Residues from 46 eggs collected from 36 breeding areas.
[2] Productivities based on outcomes of 886 occupied breeding areas.
[3] Number of fledged young per occupied breeding area.
[4] Percent success rate of occupied breeding areas.

These elevated organochlorine residues in Great Lakes bald eagles also is consistent with the elevated levels of these contaminants in other Great Lakes biota. The bald eagle's position as an upper trophic level predator enables it to bioaccumulate these persistent chemicals from a diverse prey base. This feature is complemented by studies in Wisconsin and Michigan which suggest that Great Lakes eagles forage on a higher percentage of avian prey, particularly aquatic feeding birds such as waterfowl, gulls and other colonial waterbirds, than eagles nesting inland (Kozie and Anderson 1991, Bowerman and Giesy 1991).

Those avian prey also are elevated in organochlorine compounds well above those levels found in fish and other aquatic organisms upon which these species forage. These additional trophic levels that are used as prey have contributed to some of the highest organochlorine residues in addled eggs and blood ever encountered in eagles (Wiemeyer et al. 1984, Bowerman 1991, Bowerman and Giesy 1991).

The toxicological significance of the PCBs to developing bald eagle embryos was evaluated by means of PCB congener-specific analysis and the H-4-II E bioassay on two addled eggs from Michigan (Kubiak 1990). Table 2 gives the results of these two methods compared to total PCB measures using standard methods.

Table 2. PCBs in Two Addled Bald Eagle Eggs as Estimated by Four Methods.

	Total PCBs		TCDD Equivalents Attributable to PCBs	
Location	Standard Methods (OC Scan)	Congener Specific Analysis	Congener Specific PCB Analysis	Enzyme Bioassay (H-4-II E)
L. Huron	96 ug/g	98 ug/g	31,000 pg/g	1,065 pg/g
L. Michigan	51 ug/g	83 ug/g	21,000 pg/g	560 pg/g

The extract bioassay results are consistently lower than equivalents derived from analytical chemistry, suggesting some biological antagonism. The congener specific analysis provides a measure of the total toxicity possible via a summation of the concentrations of the individually detected congeners, expressed as 2,3,7,8-TCDD equivalents. Equivalents are the concentration of each congener multiplied by their respective dioxin equivalency factors, which are laboratory-derived measures of a congener's ability to induce a hepatic enzyme response, relative to the most toxic dioxin, 2,3,7,8-TCDD. The enzyme potency of dioxin-like compounds correlates well with known toxic responses such as teratogenicity, growth retardation and immunosuppression in laboratory animals. The bioassay method is a direct in vitro measure of hepatic enzyme induction, relative to 2,3,7,8-TCDD, for the dioxin-like mixture of PCB congeners in a sample. This H-4-II E extract assay takes into account interactions (synergism, antagonism, etc.) among the individual congeners; the degree of which is approximated by the difference between the two measures of total toxicity. One egg was obtained from a nest along the northern Lake Michigan shoreline of Big Bay de Noc, and the other from the western Lake Huron shoreline of Thunder Bay.

The TCDD equivalents come almost exclusively from one PCB congener, IUPAC 126 (3,3',4,4',5-) from both sites. All four analyses show significant contamination by PCBs. To place these data in perspective, 0.87 ug/g total PCB (wet weight) is the lowest observable effect level (LOAEL) in studies of bird reproduction (chickens) (Britton and Huston 1973) and 5-15 ug/g clearly impairs hatchability of chicken eggs (see review in Kubiak et al. 1989). Forster's terns, other colonial waterbirds and bald eagles on the Great Lakes exceed the LOAEL (Kubiak et al. 1989, Government of Canada 1991, U.S. Fish and Wildlife Service, unpublished data). At the other end of the spectrum, 1,000 pg/g (parts per trillion) actual 2,3,7,8-TCDD injected into the eggs of white leghorn chickens completely inhibits hatching of chicks (100% mortality) (Higginbotham et al. 1968). The no observable adverse effect level (NOAEL) for white leghorn chicken embryos, injected with actual 2,3,7,8-TCDD, is 20 pg/g in the egg contents, excluding the shell (Verret 1976). If bald eagles are as sensitive as chickens, which our regression data using total PCBs and productivity measures seem to indicate, then PCBs are occurring at embryotoxic concentrations. Work is underway by us to similarly assess the entire archived set of addled eggs from Michigan and Ohio, using the H4IIE extract bioassay and congener-specific chemistry.

In Michigan, inland breeding areas, which are currently accessible to Great Lakes anadromous fish runs, have lower measures of productivity than shoreline breeding pairs (Appendix 8). The anticipated proposals to extend anadromous fish further inland, via fish ladders and dam removals, threaten to compromise currently productive inland breeding areas. If unrestricted fish passage facilities are installed on the Manistee, Muskegon, Au Sable and Thunder Bay river systems, up to 40 additional eagle pairs could be exposed to Great Lakes fish contamination (Appendix 9). This represents fully 25% of the existing 158 pairs which nest inland in Michigan.

Currently, studies are nearing completion which are attempting to determine the existence and extent of the possible linkage between Great Lakes fish and eagle reproductive success in the river systems under consideration for fish passage. These studies are being funded by the Consumers Power Company, owner/operator of hydroelectric facilities on three of the four river systems. The data generated by these studies (fish contaminants data) are used by us to independently assess the hazards to inland fish and wildlife via a methodology discussed later in the Hazard Assessment section of this paper.

The mink is another species which is being used to determine Great Lakes ecosystem health. Little information exists in the basin regarding the status of the mink population. It is emphatically known that mink are extremely sensitive organisms to PCB and 2,3,7,8-TCDD intoxication, especially reproductive toxicity. As little as 1 ug/g total PCB in the liver of an adult female mink will cause reproductive impairment and 5 ug/g is sufficient to result in adult mortality. Only 4.2 ng/g as a single dose of 2,3,7,8-TCDD will kill 50 % of adult mink (see review by IJC 1989). In areas where fish and other prey contamination is high, mink populations have probably been significantly reduced, except for contaminated areas where wandering immature individuals are trying to pioneer new territories. This information has been developed on Lake Ontario, on both the Canadian and American shorelines (see reviews by Government of Canada 1991, Gilman et al. 1991). Foley (1991) showed that mink, even juveniles, can become severely contaminated when associated with a source of contaminated food. Specifically, mink livers were high in typical oragnochlorine contaminants in the Salmon River watershed, a tributary to eastern Lake Ontario. The Salmon River supports a large anadromous run of chinook and coho salmon. Because so little field biology has been accomplished, especially in Michigan, ELFO has relied on feeding Great Lakes fish to captive mink to produce dose-response data that can be used and compared to environmental samples of mink or their food. Because the feeding studies are quite definitive, ELFO can arrive at fish concentrations likely to cause reproductive impairment in mink. While the primary purpose is to use these data to initiate cleanup requirements for the Lakes or for specific natural resource damage assessments, this understanding also has value for the contaminated anadromous fish issue. The reader should consult the information presented in the hazard assessment section of this paper to obtain fish contaminant criteria for mink.

The impacts to Great Lakes biota from contaminants has long been acknowledged by the Service and has resulted in our involvement in multiagency actions to resolve and remediate these impacts. The Service's release of "The Challenge" document under our Great Lakes Initiative identifies the problem of deformities, tumors and reproductive disorders in Great Lakes biota as a continuing challenge to Service programs. The document further envisions strategies and remedies to minimize impacts to biotic indicators and prevent contamination of new areas.

In testimony on May 2, 1990 before the House Public Works and Transportation Committee, Subcommittee on Water Resources, U.S. Fish and Wildlife Service Region 3 Director, James Gritman, mentioned the specific problems of poor reproduction and high contaminant concentrations encountered by bald eagles along the Great Lakes shorelines.

In implementing the Great Lakes Water Quality Agreement (Agreement), revised and amended in 1987, the Regional Director recognized the need to assess the health of ecosystem indicator species and their habitats, such as the proposed bald eagle. The Regional Director concluded that achievement of the goals and objectives of the Agreement can best be demonstrated through the health of the fish and wildlife resources, as exemplified by the rehabitation and successful reproduction by bald eagles and mink along the Great lakes shorelines.

Our interest in preserving and protecting inland populations of fish and wildlife is an extension of our continuing efforts to remediate contaminant impacts to Great Lakes biota.

HAZARD ASSESSMENT SUMMARY

The basic purpose of this hazard assessment is to utilize existing data to determine the degree of potential hazard associated with wildlife exposure to contaminants of concern in anadromous fish. These fish are potential migrants into stream segments that are currently experiencing no Great Lakes migratory salmonids or other species because current dams form a barrier to their migration. Depending on the individual species, contaminant concentrations could be sufficiently high to cause adverse biological effects to sensitive wildlife species which prey on these species. This hazard assessment is focused on the amount of exposure that can be tolerated by key wildlife indicators, the bald eagle and mink. Exposure can be determined in two different ways. First, the amount/concentration of exposure can be determined by knowing the mix of forage items commonly eaten, contaminant uptake, absorption and depuration rates, contaminant concentration in forage items, grams of food eaten per kilogram of wildlife predator body weight, and a model feeding study where known adverse toxicological endpoints were measured so as to determine a "No Observable Adverse Effect Level" (NOAEL). Alternatively, a pollutant which can biomagnify in the food chain such as DDE, PCBs and dieldrin can be modeled based on known biomagnification from field data generated on a more site specific basis. If the measured concentration in a specific tissue or organ can be obtained and related to controlled experiments where threshold concentrations have been determined (NOAEL or Lowest Observable Adverse Effect Level, a LOAEL), then a simplified model based on measured biomagnification factors can be developed. For birds, the most sensitive endpoint/tissue is the egg and effects on the developing embryo. For the mink, the most sensitive tissue known is liver. Both eggs and livers can be analyzed for specific contaminants and their respective concentrations determined. For mink, the laboratory derived forage concentration for PCBs, DDE, and dieldrin that produces adverse and no adverse effects (NOAEL) is known as well.

While it is possible to develop a model using the former approach identified above, the data are not sufficiently developed for species on the Great Lakes. Sufficient data are available from field monitoring and laboratory studies of sensitive species to begin to construct a model from pollutants which are biomagnified in the food chain. Using this fact, we have built a simple hazard assessment model which has three basic components for the assessment of wildlife health. These are: 1. the degree of exposure of individual species' most sensitive lifestage and endpoint above laboratory LOAEL/NOAEL data of similar lifestage and endpoint (termed exceedance over NOAEL); 2. the degree of magnification of a contaminant from forage to target organ/egg, (termed forage to egg/organ biomagnification factor, BMF), and 3. forage fish contaminant concentration. The exceedance over NOAEL number and the target forage number are equal goals (target numbers) that are required to provide a reasonable level of assurance that adverse effects are not going to occur as a result of excessive contaminant exposures. The most sensitive species/endpoint is a most common hazard assessment approach used in regulatory agencies to obtain a reasonable amount of protection. For instance, we would propose to have the exceedance over NOAEL be less than 1, and the forage fish target to be significantly reduced in accordance with an individual pollutant's exceedance over NOAEL or the BMF.

FORAGE FISH CONCENTRATION
EXCEEDANCE OVER NOAEL/LOAEL

OR = **TARGET FORAGE FISH CONCENTRATION**

EAGLE EGG NOAEL/LOAEL
FORAGE TO EGG BMF

The following pollutants, DDE, dieldrin, PCBs and 2,3,7,8-TCDD equivalents have been the focus of considerable interest and investigation for bald eagles. Mink are known to be sensitive to total PCBs, 2,3,7,8-TCDD-like PCB congeners, 2,3,7,8-TCDD and 2,3,7,8-TCDD equivalents (eq) (dioxin-like PCBs, dioxins and furans). The following are the NOAEL/LOAEL concentrations in eggs, with lab data being considered NOAEL concentrations and field derived data being considered the LOAEL concentrations that are used in conjunction with the residue chemistry of the forage species of interest in the field to obtain the exceedance over NOAEL/LOAEL:

Total PCBs in chicken egg = 0.4 ug/g (lab, Britton and Huston 1973)
Total PCBs in Eagle Egg = 4.0 ug/g (field, Wiemeyer et al. 1990)
DDE (Total DDT and metabolites) in eagle egg = 1.0 ug/g (field, Wiemeyer et al. 1984)
Dieldrin in eagle egg = 0.1 ug/g (field, Wiemeyer et al. 1984)
2,3,7,8-TCDD (and equivalents) in chicken egg = 20.0 pg/g (lab, Verret 1976)

Recent field data developed by us on addled bald eagle eggs from Lakes Michigan and Huron are provided below:

		Lake Michigan (year)	Lake Huron
Total PCB	=	83 ug/g (1986)	98 ug/g (1986)
Total DDE	=	34.6 ug/g (1986)	44.6 ug/g (1986)
dieldrin	=	2.2 ug/g (1986)	2.5 ug/g (1986)
2,3,7,8-TCDD eq^{H4IIE}	=	560 pg/g (1986)	1065 pg/g (1986)
2,3,7,8-TCDD $eq^{congeners}$	=	21000 pg/g (1986)	31000 pg/g (1986)

The exceedance over the NOAEL/LOAEL is determined by dividing the NOAEL/LOAEL concentration in a bird egg into the maximum concentration in an environmental sample:

Wild Bird Egg Concentration = **Exceedance over NOAEL/LOAEL**
Bird Egg NOAEL/LOAEL (field or laboratory derived)

Exceedances Over NOAEL/LOAEL

	Lake Michigan	Lake Huron
Total PCB (NOAEL)	208	245
Total PCB (LOAEL)	21	25
DDE (LOAEL)	35	45
Dieldrin (LOAEL)	7	8
TCDD eq^{H4IIE} (NOAEL)	28	53
TCDD $eq^{congeners}$ (NOAEL)	1050	1550

Other more recent data obtained in the Saginaw River and Bay in 1990 are generally consistent for total PCBs, DDE and dieldrin. These data provide strong evidence for excessive contamination and the large exceedances over lab-derived NOAELs or field-derived LOAELs indicate a continuing threat to successful reproductive outcomes in the field. These data also are consistent with the data for total PCBs, DDE and dieldrin data generated by the Service and discussed previously in the Background Section of this paper. These data show a reduction of these pollutants from a few fold to over two orders of magnitude is required to reduce or eliminate the reproductive risks to the bald eagle on the Great Lakes and tributaries accommodating anadromous fish runs. The potential biological threat to "cleaner" eagle nesting pairs isolated from Great Lakes fishes by barrier hydroelectric dams becomes increasingly obvious, given the introduction of contaminated anadromous fish from the Great Lakes and tributaries, the higher contaminant exposure that would result and the inverse relationship between higher exposure and reduced reproductive success in eagles.

The Canadian Wildlife Service has been monitoring the herring gull on the Great Lakes since the early 1970's. Recently published data has allowed for the development of forage to egg magnification factors (Braune and Norstrom 1989). In addition, ELFO has developed data on the food chain of Thunder Bay, Lake Huron which shows considerable magnification in this foodchain for 2,3,7,8-TCDD eq as measured by the H4IIE extract bioassay (U.S. Fish and Wildlife Service and Michigan State University unpublished data). In the Thunder Bay ecosystem, alewife are 11 pg/g, while higher organisms range to the hundreds of pg/g and the bald eagle on the pinnacle of the food chain with an addled egg concentration of 1065 pg/g (Appendix 10). Considering that the alewife is a major forage item of the herring gull, the key magnification factors from alewife to herring gull egg are included as follows (Appendix 11):

Forage to Egg Magnification Factors (BMF)

Alewife Whole Body to Herring Gull Egg

	Forage	Egg	EGG/FORAGE
Total PCBs	0.50 ug/g	16.0 ug/g	= 32
DDE	0.16 ug/g	5.4 ug/g	= 34
Dieldrin	0.017 ug/g	0.1 ug/g	= 7

Alewife Whole Body to Bald Eagle Egg

2,3,7,8-TCDD eq^{H4IIE}	11 pg/g	1065 pg/g	= 97

Northern Pike Whole Body to Bald Eagle Egg

2,3,7,8-TCDD eq^{H4IIE}	57 pg/g	1065 pg/g	= 19

Herring Gull Adult to Bald Eagle Egg

2,3,7,8-TCDD eq^{H4IIE}	469 pg/g	1065 pg/g	= 2

Because the bald eagle sits at the top of the foodchain, the BMF for 2,3,7,8-TCDD eq is higher than the rest because there are extra trophic levels of predatory fish and other wildlife forage between the eagle and traditional forage fish (alewife) in the Great Lakes. For instance, the northern pike collected as part of our Thunder Bay trophic level study showed considerably more contamination than the traditional forage fish of the lake; 57 pg/g vs 11 pg/g. Because the bald eagle preys on birds as well as fish, it could be hypothesized that most contaminants in eagles today come from the contaminated birds such as gulls and cormorants. For instance, adult herring gull whole body analyses from Lake Huron contained 469 pg/g 2,3,7,8-TCDD eqs. in 1989. Colonial waterbird species are much more contaminated than fish. However, the very low magnification factor from adult gull to eagle egg indicates that the majority of the contaminant burden arises from the fish forage base which has a BMF of greater than ten and is consistent with total PCB and DDE BMFs. This fact strongly suggests Great Lakes fish are playing the key role in the contamination of the coastal breeding population of bald eagles and the threat anadromous fish will have if their contaminant concentrations are excessive.
Further evidence for fish being the dominant source of eagle egg contamination can be seen from the use of the herring gull model (Appendix 11). For instance, the forage to egg BMF for total PCBs in the herring gull model is 32. For the Thunder Bay eagle egg, the total PCB concentration was 98 ug/g. Dividing this concentration by the herring gull model BMF (98/32) equals the average forage concentration of 3 ug/g. Concentrations of PCBs in Chinook salmon at the Au Sable river were 1.6 ug/g, 0.7 ug/g for Northern Pike and 2.2 ug/g for walleye (Consumers Power 1991b).

Carp fillets from Lake Huron near the Thunder Bay River mouth have reported mean total PCB concentrations to be approximately 2 ug/g, with a high of 3.8 ug/g (Michigan DNR 1990). Multiplying these fish concentrations by the BMF of 32 for total PCBs predicts that a large percentage of the 98 ug/g total PCB could easily come from these species of fish.

Certain species appear to be equisensitive to dioxin-like compounds as the domestic chicken. Work done by Kubiak and co-workers (1989) on the Forster's tern on Green Bay, Lake Michigan in 1983 found reproductively impaired terns on Green Bay, but not on Lake Poygan, an inland breeding site used as a reference colony. Statistically different concentrations were found in PCBs, PCB congeners, and 2,3,7,8-TCDD and other chlorinated dioxins. More recently, the H4IIE extract bioassay was conducted on archived eggs from this study. The Lake Poygan reference site had 20 pg/g 2,3,7,8-TCDD eqs while the Green Bay tern eggs had approximately 200 pg/g (Tillitt et al 1988). Further work done cooperatively with the Canadian Wildlife Service, Ecological Research Services, Inc., Michigan State University and The Green Bay and East Lansing Field Offices has shown a significant statistical relationship between double-crested cormorant egg mortality and the amount of 2,3,7,8-TCDD eqs from the H4IIE extract bioassay (Tillitt et al. submitted for publication). The lowest amount of 2,3,7,8-TCDDeqs came from a Canadian prairie reference site in Manitoba. All other eggs were Great Lakes eggs and contained higher equivalents and poorer egg hatching success. Appendix 12 shows this relationship.

Because the above pollutants are shown to be excessive, it is necessary to establish fish target concentrations which will not produce concentrations above NOAELs for eagle eggs. This is accomplished by using the formula presented here. Fish concentrations must be reduced to compensate for biomagnification and exceedances over respective NOAELs/LOAELs.
The equations are:

$$\frac{\text{FORAGE FISH CONCENTRATION}}{\text{EXCEEDANCE OVER NOAEL/LOAEL}} = \text{TARGET FORAGE FISH CONCENTRATION}$$

OR

$$\frac{\text{EAGLE EGG NOAEL/LOAEL}}{\text{FORAGE TO EGG BMF}} = \text{TARGET FORAGE FISH CONCENTRATION}$$

Using either equation, it is possible to provide a reasonable estimate of fish contaminant concentrations necessary to achieve estimated NOAEL concentrations in eagle eggs. In this manner, contaminant concentrations can be assessed relative to eagles by knowing egg and forage concentrations. The utility of the fish concentrations is that they are readily monitored whereas only dead bald eagle eggs can be collected for analysis and not all of these are available due to scavenging by predators or destruction by adults. The numbers generated by this approach can be used by the Service and others interested in the issue to evaluate fish concentrations generated by relicense applicants as part of their prelicensing studies. If existing inland fish contaminant concentrations come close to the target concentrations for Great Lakes influenced fish generated from the above calculations, this provides significant additional evidence for concern regarding passage of contaminated Great Lakes fish to inland areas.

The BMF values for the alewife to herring gull egg can be used as the BMF number to determine the target fish value (Appendix 11), unless site specific data are available, as is the case Thunder Bay and Au Sable River fish and wildlife. The following are the calculation summaries to project required forage fish concentrations for passage:

Bald Eagle Egg PCB Target (NOAEL) = 0.4 ug/g; LOAEL = 4.0 ug/g
Bald Eagle Egg, 1986, Thunder Bay, Lake Huron, USFWS data,
Total PCB = 98 ug/g
Chinook Salmon from Lake Huron, Consumers Power data, Au Sable River,
Total PCB = 1.657 ug/g; BMF = 98/1.657 = 59
Bald Eagle PCB Chinook Salmon Target (food NOAEL) = 0.4/59 = 0.0068 ug/g
Bald Eagle PCB Chinook Salmon Target (food LOAEL) = 4.0/59 = 0.067 ug/g

Bald Eagle Egg DDE Target (NOAEL) = 1.0 ug/g
Bald Eagle Egg, 1986, Thunder Bay, Lake Huron, USFWS data,
p.p'-DDE = 44.6 ug/g
Chinook Salmon from Lake Huron, Consumers Power data, Au Sable River,
p,p'-DDE = 0.275 ug/g; BMF = 44.6/0.275 = 162
Bald Eagle DDE Chinook Salmon Target (food LOAEL)= 1.0/162 = 0.006 ug/g

Bald Eagle Egg Dieldrin Target (LOAEL) = 0.1 ug/g
Bald Eagle Egg, 1986, Thunder Bay, Lake Huron, USFWS data,
Dieldrin = 2.5 ug/g
Chinook Salmon from Lake Huron, Consumers Power data, Au Sable River,
Dieldrin = 0.021 ug/g; BMF = 2.5/0.021 = 119
Bald Eagle Dieldrin Chinook Salmon Target (food LOAEL)= 0.1/119 = 0.001 ug/g

Bald Eagle Egg TCDD eq^{H4IIE} Target (NOAEL) = 20 pg/g
Bald Eagle Egg, 1986 Thunder Bay, Lake Huron, USFWS data,
TCDD eq ^{H4IIE} = 1065 pg/g
Northern Pike, 1989, Thunder Bay, Lake Huron, USFWS data,
TCDD eq^{H4IIE} = 57 pg/g; BMF = 19
Bald Eagle TCDD eq^{H4IIE} Northern Pike Target (food NOAEL) = 20/19 = 1.0 pg/g

Alewife, 1989, Thunder Bay, Lake Huron, USFWS data,
TCDD eq^{H4IIE} = 11 pg/g; BMF = 97
Bald Eagle TCDDeq^{H4IIE} Alewife Target (food NOAEL) = 20/97 = 0.2 pg/g

Chinook Salmon, from Lake Huron, Consumers Power data, Au Sable River,
TCDD eq ^{H4IIE} = 21 pg/g; BMF = 51
Bald Eagle TCDD eq^{H4IIE} Chinook Salmon Target (food NOAEL) = 20/51 = 0.4 pg/g

White Sucker, from Lake Huron, Consumers Power data, Au Sable River,
TCDD eq^{H4IIE} = 6 pg/g; BMF = 178
Bald Eagle TCDD eq^{H4IIE} White Sucker Target (food NOAEL) = 20/178 = 0.11 pg/g

Common Carp, from Lake Huron, USFWS data, collected by ERS, Au Sable River,
TCDD eq^{H4IIE} = 109 pg/g
Bald Eagle TCDD eq^{H4IIE} Common Carp Target (food NOAEL) = 20/10 = 2.0 pg/g

Bald Eagle Egg $TCDDeq^{congeners}$ Target (NOAEL) = 20 pg/g
Bald Eagle Egg, 1986, Thunder Bay, Lake Huron, USFWS data,
TCDD $eq^{congeners}$ = 31000 pg/g (Exceedance over NOAEL = 1550 based on AHH enzyme potency factors)
Bald Eagle $TCDDeq^{congeners}$ Fish Target (food NOAEL) = to be determined if Consumer's Power provides adequate QA/QC report in response to recent Service review.

It should be recognized in the interpretation of the derived fish contaminant concentrations that assumptions are made concerning the diet of an eagle. These concentrations are based on the assumption that an eagles egg obtains all its contamination from the area where the fish was caught and that the egg obtains all contaminant concentrations from one species only. These assumptions are necessary to obtain fish target concentrations since feeding preferences of individual eagles are not documented for species mix and relative mass consumed. Thus, a proportional diet approach cannot be utilized. We are also using the Thunder Bay eagle egg as the maximum contaminated egg. The Thunder Bay ecosystem and the Au Sable River area to the south of Thunder Bay are close geographically and likely have little difference in overall contamination. We are therefore using these numbers as the fish target numbers for the two river systems on Lake Huron (Thunder Bay and Ausable) and the two river systems on Lake Michigan (Muskegon and Manistee). Continued efforts will allow further refinement in approach which should be more site specific for Lake Michigan.

The target Great Lakes fish concentrations for total PCBs and 2,3,7,8-TCDDeqs above closely approximate the concentrations of respective contaminant parameters from inland portions of the river systems above the lowermost barrier dams that were surveyed by the licensee, Consumers Power Co. and indicate that the concern regarding the passage of anadromous fish to inland river reaches above the lowermost barrier dam will have adverse effects on the bald eagle and contaminate other fish and wildlife. The above model data for DDE and dieldrin target fish concentrations do not correspond as well as the above parameters and may overestimate required decreases in concentrations of Great Lakes fish. One possible reason for this is the inability of an eagle to metabolize these pesticides as rapidly in the presence of much higher PCB concentrations that are present in the Great Lakes fish relative to comparable fish species above the lowermost dams in the respective Great Lakes tributary watersheds.

The hazard assessment on mink is based on the total PCB and 2,3,7,8-TCDD equivalents from the joint Service sponsored study of ecosystem indicators between ELFO and Michigan State University (MSU) (Heaton et al. 1991). We are unable to provide full target number data for

PCB congeners and cóngener chemistry derived 2,3,7,8-TCDD equivalents because these data have not been generated as yet. The other pesticide data are not considered controlling factors in reproductive problems in mink. Earlier studies (Aulerich and Ringer 1970, Aulerich et al. 1972) have shown these pollutants cannot cause reproductive problems at concentrations of 150 ug/g DDE and 5.0 ug/g dieldrin in their diets. Great Lakes fish do not have concentrations approaching these NOAELs for food quality. Conversely, the concentration of total PCBs or 2,3,7,8-TCDD equivalents in the diet which can produce effects on reproduction are much lower. The ELFO/MSU study has generated sufficient data to determine the NOAEL for each of these parameters (Heaton et al. 1991). These are liberal NOAELs in that they were generated with short-term feeding studies centering on a single reproductive period, not a long-term (1-3 years) feeding study, with multiple reproductive cycles or multigeneration testing. Based on our study's reproductive outcomes, the NOAEL concentration in the diet is 0.069 ug/g total PCBs and 1.9 pg/g 2,3,7,8-TCDD equivalents as determined by the H4IIE extract bioassay. We are in the process of identifying the respective concentrations for individual congeners and congener sums (as 2,3,7,8-TCDD equivalents).

In view of the above data on mink, we anticipate that passage of anadromous fish above the NOAELs for total PCBs and H4IIE bioassay derived equivalents will compromise reproductive success in mink. The degree of impaired reproduction will depend on the amount of fish utilized and the background concentrations in fish in the upstream reaches of the rivers of interest. Anadromous fish contaminant concentrations above upstream background will add to any potential reproductive impairment in the upstream reaches, which is currently hypothesized to be slight and not detectable.

In addition to the quantitative data on the hazards of introducing contaminated, anadromous fish to upstream areas as part of the FERC relicensing program in Michigan, there is another potentially significant contaminant issue to consider during relicensing. As more contaminated fish move to upstream, cleaner areas, the potential of secondary contamination of the existing aquatic ecosystem in the cleaner reaches increases according to the amount of fish passed yearly and over the life of any authorization to pass anadromous fish. Examples exist in Michigan and in the province of Ontario which show the movement of contaminants via Great Lakes fish into indigenous fish populations. Concentrations in Michigan brook trout, from Lake Michigan tributaries, eventually exceeded the Federal Food and Drug Administration's tolerance level for total PCBs (currently 2.0 ug/g) (Merna 1986). Recently published data shows that Lake Michigan chinook salmon eggs, which contain 116 pg/g 2,3,7,8-TCDD equivalents (as determined by the H4IIE extract bioassay), are 4-fold higher in 2,3,7,8-TCDD equivalents than dorsal muscle from the same fish (Tillitt et al 1990). Fish eggs are readily used as food for a variety of aquatic organisms (Low 1983, Merna 1986, Scrudato and McDowell 1989) . Further, work on Lake Ontario has shown such high transport of mirex into a stream by salmon, that water quality specialists believe the mirex mass that would eventually move down to Lake Ontario would be large enough to warrant considering it in any mass balance studies of the mirex budget in the Lake (Lewis and Markarewicz 1988). Secondary contamination of other aquatic oriented wildlife can be expected through the passage of anadromous fish to new reaches of streams (Foley 1991).

CONCLUSIONS AND RECOMMENDATIONS

There is sufficient information available to know that the bald eagle continues to expand its population in the basin, in Michigan, and the Great Lakes shorelines and tributaries. ELFO has developed sufficient information to determine that the bald eagle is reproductively impaired on streams accommodating anadromous fish runs and along the Great Lakes shorelines. The high coefficients of determination (r^2) in the regression analyses indicate that the majority of the impairment is contaminant induced. Data developed by us and others also show that Great Lakes fish are the predominant source of this contamination, as judged by representative examination of biomagnification factors from food to eagle eggs. As a result of examination of the epizootiological and hazard assessment information, we have determined that contaminated fish pose a continuing threat to the bald eagle inhabiting the Great Lake's shorelines and certain tributaries. Passage of anadromous fish will need to be considered in a Section 7 consultation between the Service and the FERC given that the Bald Eagle is present within the project area river basins and may be affected by relicensing decisions by the FERC. Existing data on egg residues from varied Great Lakes locations strongly suggests that passage of anadromous fish at lowermost FERC licensed dams would affect the inland population of the bald eagle. In view of this finding, we recommend that passage of anadromous fish in an unrestricted manner be reserved as a prescriptive condition until the following are met:

1. That the bald eagle is reproducing successfully on Great Lakes shoreline/anadromous fish-influenced tributaries, as judged by levels of reproductive performance which are currently well established and agreed to by eagle experts,

2. that anadromous fish have levels of contamination that will not have appreciable influence on eagle egg residues when considering biomagnification and necessary reductions in existing egg concentrations,

3. that sufficient effort is maintained to track this key issue and develop new information to enhance our understanding of the progress of the bald eagle on the Great Lakes and tributaries. We recommend a continued effort be made by the resource management agencies and licensees to contribute funds/expertise to assure that this is accomplished.

Regarding other programs, we find that a failure to reserve the prescription for fish passage, until contaminants have been sufficiently reduced by other program initiatives, has the real potential to undermine the basic foundations of an ecosystems approach to the restoration of Great Lakes water quality and impaired beneficial uses under the Water Quality Agreement and other Federal statutes. Our use of the natural resource damage assessment process to focus on key species, such as the eagle, mink and colonial waterbirds would be effectively compromised if unrestricted anadromous fish passage and the attendant contaminant effects were condoned. In fact, loss of the management flexibility to prescribe passage because of the contaminant issue can be considered a lost use and injury to trustee fisheries resources and be part of a natural resource damage claim. Further, we would be tacitly agreeing to further degradation of waters and species that are now mostly protected by barrier dams low in the respective watersheds. Therefore, we recommend the following:

1. the implications towards other contaminant initiatives and programs must be thoroughly weighed against possible approval of unrestricted anadromous fish passage. For instance, our arguments in seeking damages for contaminant-related injury may be used against the Service as setting double standards for program goals and weaken our negotiating position with polluters beyond repair.

2. Cross-program consistency between the ELFO (Contaminants and FERC), Endangered Species, Fisheries and the Federal Aid programs needs to be clear and orchestrated consistent with program needs and responsibilities. ELFO believes more can be gained by a unspecified term of reserving but not initiating passage as a FERC license condition, especially where we may actually claim the lack of fish passage as a natural resource damage because of the contamination and the attendant economic losses that would result. This would provide the necessary impetus to seriously undertake additional cleanup actions that will ultimately result in cleaner fish, healthier wildlife populations and reduced threats of contaminants constraining other programmatic initiatives, such as anadromous fish passage.

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